Is the San Andreas a Transform Fault?

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INTRODUCTION

According to the paradigm of plate tectonics, the San Andreas is a transform fault. It was called a ridge-ridge transform when this class of fault was first proposed (Wilson, 1965). Right-slip movement on the fault was interpreted as being terminated and transformed at the northeast end of the East Pacific Rise and at the south end of the Gordo Ridge by the addition of oceanic crust from these spreading centers. Although this tectonic model is commonly accepted, it is not confirmed, and therefore complete acceptance may be premature. Thus justified, I present objections, alternatives, and doubts to counteract its possibly dogmatic application to plate tectonics.

DISCUSSION

The San Andreas fault zone is the principal structure within an 800-km-wide belt of northwest-trending right-slip faults (the San Andreas set of the San Andreas system; Hill, 1971a). None of these faults, including the Agua Blanca, San Clemente, Newport-Inglewood, Elsinore, San Jacinto, Death Valley, Furnace Creek, and Las Vegas zones, is known to offset crustal spreading centers (Fig. 1). Therefore, perhaps the San Andreas, which only differs from the other faults by greater length and cumulative slip, also does not offset the extension of the East Pacific Rise to the Gordo Ridge. Or by analogy to maps of ridge-ridge transform faults in oceanic crust, if this belt of faults across the zone from the Agua Blanca fault to the Las Vegas shear represents one transform zone, the East Pacific Rise and the Gordo Ridge should be truncated by it. However, neither the Agua Blanca nor the Las Vegas fault reaches these spreading centers. Furthermore, if other faults that lie southwest of the San Andreas—for example, the active San Jacinto zone—offset the East Pacific Rise, there should be evidence for other offsets in order to bring the rise to the San Andreas in the vicinity of the Salton Trough "hot spot" or elsewhere. Conversely, if the East Pacific Rise reached any fault lying northeast of the San Andreas, there would appear to be no way to offset it to the Gordo Ridge or to bring it back to the San Andreas zone. Furthermore, why is the San Andreas zone of faults apparently active in northwest Sonora, Mexico, in an area that is not between ridge ends (Merriam, 1968)? Therefore, the San Andreas fault zone does not appear to be the simple transform so often depicted on small-scale maps.

Another important set of faults (Garlock set; Hill, 1971a) must not be ignored in any analysis of the role of the San Andreas in the tectonics of southern California. These are the east-northeast- to east-trending left-slip (and reverse left-slip) faults, such as the Garlock, Big Pine, Santa Ynez, Pinto Mountain, and Blue Cut fault zones (Fig. 1), with cumulative displacements up to tens of kilometers. The Garlock has been interpreted as a transform fault (Davis and Burchfiel, 1973), but if so, the others of this set (for example, the Pinto Mountain fault which, like the Garlock, is truncated at a bend of the San Andreas) should also be transforms. However, no evidence is found for offset spreading centers or subduction zones analogous to those in oceanic crust. On the other hand, strain analysis allows these faults to be part of the San Andreas strain system of conjugate shears. Thus the Garlock set of left-slip faults and the San Andreas set of right-slip faults help produce the regional north-south crustal shortening and east-west relative extension. This north-south shortening, where the extension (relief) is wholly or in part upward, also produces the east-west folds and reverse faults of the Transverse Ranges, the east-west reverse left-slip faults (like the San Fernando fault), and the changes in strike along the San Andreas on the north (Garlock) and south (Pinto Mountain) sides of the Transverse Ranges by relatively greater components of dip-slip on the San Andreas in these positions. The so-called bends of the San Andreas, however, may be more geometric than kinematic, and therefore they may not function entirely as frictionally locked segments of the fault zone.

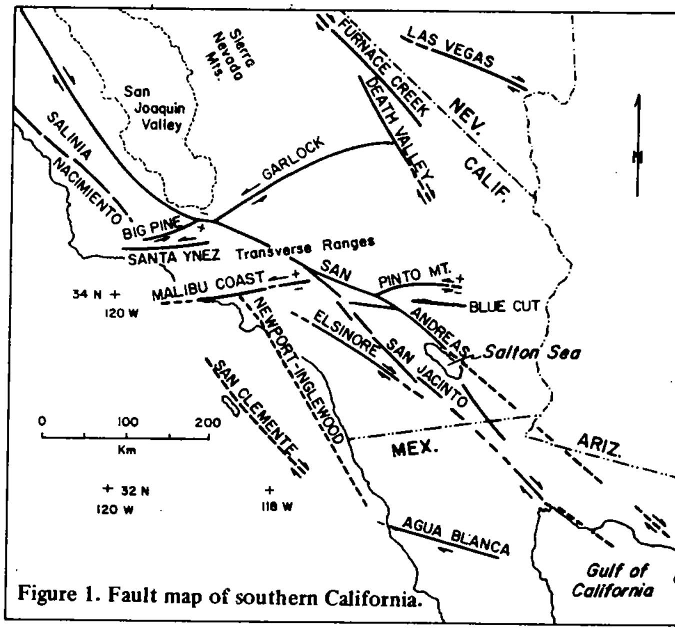

Figure 1. Fault map of southern California.

If the foregoing regional strain analysis is essentially correct, it would seem impossible for the Garlock set of faults and the Transverse Ranges folds and faults to be subsidiary draglike structures due to movement on the San Andreas fault. Therefore, the San Andreas may not be a simple plate-bounding transform fault.

The fault system in southern California appears to be incompatible with established sea-floor spreading patterns in at least two important respects: (1) assuming the San Andreas is a transform fault, the associated structures should tend to be parallel (to other transform faults) or normal (to spreading centers and magnetic anomaly stripes) to it, whereas essentially all the structures in southern California are oblique to the San Andreas, and (2) assuming that the east-west transforms of the Pacific plate (Mendocino and others) extended into the now-subducted Farallon plate, it is difficult to reconcile this pre-Pleistocene east-west telescoping of the Pacific and American plates with concurrent north-south shortening established by the

San Andreas strain system (Hill, 1971a). Therefore, because the tectonic patterns and relative movements within these oceanic and continental plates are different, there is reason to doubt that the San Andreas is a transform fault. (However, a near-vertical discontinuity in oceanic-like crust beneath the San Andreas could act as a transform fault, but to separate that strain system from the San Andreas system would appear to require another, near-horizontal discontinuity.)

The Gulf of California has been aptly called a rhombochasm that resulted from sea-floor spreading (Moore, 1973). However, have the Salton Trough, Death Valley, Owens Valley, and other similar basins been formed by the same process? If so, where are the causal spreading centers? It has been proposed that the Salton Trough is an extension of the gulf structure (Elders and others, 1972). It and several of the other basins are, however, bounded in part by right-slip shear zones that indicate a compressional rather than tensional environment, for two reasons: (1) strike-slip faults in continental crust are shears and, except locally, there is a component of compressional stress normal to the faults; and (2) the associated structures, except locally, are compressional folds and other shears, not gash (tension) faults (for example, the folds and faults in and adjacent to the Salton Trough; Dibblee, 1954). Furthermore, if these basins are local effects of strike-slip faulting, such as the well-known sag-ponds or gash fractures, then the surrounding mountain ranges should be pressure ridges or anticlinal folds (also common as subsidiary features along strike-slip faults). However, these basins and mountains are probably too large, relative to the strike-slip faults, to have been formed in this manner. Therefore, the Salton Trough and other similar basins in continental crust may not be directly related to a sea-floor spreading mechanism.

It seems geologically unrealistic for the San Andreas fault to have been initiated about 29 m.y. B.P. at a point near present Cape Mendocino and to have migrated and extended itself to the Gulf of California in approximately 25 m.y. (Atwater, 1970). Alternatively, there is strong geologic evidence that the San Andreas zone, along at least part of its present trace, has been episodically active since before Late Cretaceous time. Probable proof is that Salinia, the granite-based corridor west of the San Andreas and east of the Sur-Nacimiento fault zone (Fig. 1), has been displaced nearly 700 km by right-slip on the San Andreas zone (Hill, 1971b; Page, 1970; Hamilton, 1969). Perhaps only in this manner can the Mesozoic border of North America be repeated (the Sur-Nacimiento zone, presumably a Mesozoic subduction zone between the Farallon and American plates, is offset from the west side of the San Andreas near Cape Mendocino to the east side of the fault, near the southwest corner of the San Joaquin Valley, where the Mesozoic continental edge is marked by Sierran granitic basement rocks east of Franciscan basement). Some workers and modern textbooks (for example, Sawkins and others, 1974, p. 219) avoid the problem and significance of Salinia by drawing a Sierran to Pacific geologic section north of exposed Salinia. Others (for example, Suppe, 1970; Anderson, 1971; Nilsen and Clarke, 1972) have attempted to reconcile Tertiary Pacific plate relative motions with possible positions and movements on possible ancestral and modern San Andreas faults. Certainly most of the tectonic models that attempt to incorporate the character and history of the San Andreas as a transform fault within sea-floor spreading models are not completely convincing.

Transform faults in the Gulf of California, which separate crustal spreading centers, do not appear to extend into the continental rocks of either Baja California or Sonora, Mexico. Nor do faults of these regions appear to extend into the gulf. Thus it is possible that no transform faults occur in continental rocks and no lateral (transcurrent) faults occur in oceanic crust. If the foregoing general statement is true, distinctions between transform and lateral faults are more than semantic, although both are strike-slip faults (see Garfunkel, 1972; Freund, 1974; Hill, 1974, for discussions of transform faults versus strike-slip faults). Therefore, the San Andreas may not be a transform fault.

CONCLUSIONS

These arguments against the commonly held views that the San Andreas is a transform fault are meant to cast some doubt on the simplicity and universality of the plate tectonics hypothesis in explaining geologic history and the origins of rocks and structures in continental crust. Many other questions may be asked, such as why are some strong earthquakes not at plate edges; why has there been no movement on the Transverse Ranges segment of the San Andreas for over 100 years; what special kind of fault mechanism allows transform faults to be parallel to the direction of tectonic transport (conventional strike-slip faults are oblique to it); and what special meaning is left for transform if all strike-slip faults are transform faults?

Oceanic and continental tectonics *must* be reconciled, but it appears that more critical data, instead of ad hoc models depicted on small-scale maps, will be required before satisfactory reconciliation is obtained.

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